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ABSTRACT

Previous research has indicated that correlations between Piagetian and psychometric tests and chronological age are influenced by the size of the age range of the sample groups. To examine whether the size of the age range and mean age are related to the size of the correlations between Piagetian and arithmetic tests, Spearman rank-order correlations were obtained between these age-related variables and the Piagetian and arithmetic test correlations. Age range size was not related to the size of the Piagetian and arithmetic test correlations, however, an inverse and the size of the correlation between Piagetian and arithmetic tests, and the size of the correlation between PIagetian and arithmetic tests, indicating that groups with younger mean ages tended to have larger correlations than groups with older mean ages. The data suggest that a moderate relationship exists between Piagetian and arithmetic tests. Furthermore, no systematic differences occurred in the size of the Piagetian-arithmetic correlations between standardized and nonstandardized arithmetic tests. Many conserving children perform higher on arithmetic tests than do their nonconserving peers, although some nonconserving children nevertheless attain comparable levels of arithmetic performance. These results suggest that Piagetian tests might be used as a diagnostic aid for children who are experiencing difficulties in arithmetic. (Author/CKJ)

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Summary and Review: Correlational Studies of Measures of Piagetian Cognitive Development and Mathematics Achievement

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Paper presented at the 9th annual conference on Piagetian Theory and the Helping Professions, Los Angeles, February 1979.

Correlational Studies of Piagetian and Mathematics Tests

This paper reviews the literature on the relationship between performance on various Piagetian and arithmetic achievement tests. According to Piagetian theory, the ability to conserve, or recognize the logical invariance of a particular concept despite changes in the relationship between objects, is necessary for the understanding of many logical concepts, including mathematical reasoning. Previous research has reported moderate relationships between Piagetian tests and IQ, MA, chronological age, and reading achievement (Jordan & Brownlee, 1979; Jordan & Jordan, 1975), so it seemed appropriate to document the relationship between Piagetian and arithmetic tests.

Piaget's extensive writings on the development of the child's concept of number have many practical implications for children's arithmetic achievement. The transition from preoperational to concrete operational thought reflects important changes in the child's concept of number, such as:

1. An understanding of the cardinal and ordinal properties of number. During this time children realize that when they count eight objects, the eighth object refers to a position in that sequence, that the eighth is higher than the seventh, and that there are a total of eight objects in this collection. It is likely that the understanding of ordinal aspect of number is similar to the ability to seriate a number of objects, or to put a series of objects in a logical sequence from smallest to largest, or vice versa.

2. An understanding of numerical correspondences between two groups of N objects.

3. An understanding of the comparative-numerical value of relational terms such as "more," "less" and "equal."

4. An understanding of what types of transformations are relevant and irrelevant in terms of the logical properties of the materials. This ability to conserve, as in the case of conservation of number, reflects the recognition that certain transformations have no effect on the numerical value of objects. In contrast, children recognize when transformations such as addition and subtraction can change the numerical value of objects, and the operations of addition and subtraction are understood as inverse operations in relation to one another.

Two types of research studies have addressed the relationship between Piagetian and arithmetic tests. One research strategy has been to compare groups of children who differ in their conservation skills on a variety of arithmetic tests. A search of the literature has so far revealed three studies of this kind, and all studies reported that conserving children performed significantly higher than nonconserving children on both standardized and nonstandardized arithmetic tests. The second research strategy has examined the relationship between Piagetian and arithmetic tests through correlational methods. These studies are more numerous than the comparative studies, so the remainder of this paper summarizes the findings from these correlational studies.

Method

Sample

The basic unit of analysis was groups of subjects drawn from studies which met the following criteria:

1. Only studies in which Piagetian tests were administered to intellectually normal children from the preoperational through formal operational periods were included.

2. Studies were not restricted in range of IQ. Studies involving only retarded or only gifted children, or children only within the IQ range of 90 to 110 were not included. However, only 7 of the 16 studies included reported any information concerning IQ characteristics of their sample.

3. The age range of the subjects was continuous. For example, if a study tested children in the first, third and fifth grades, but used correlations for the entire group, then these data were not included. However, if the study reported correlations for each of these groups separately, then these data were included and each group treated as an independent sample.

4. The relationship between Piagetian and arithmetic tests was reported using product-moment correlations. Studies which used rank-order correlations, biserial correlations, and the like, were not included.

On the basis of these criteria, 16 studies have been obtained at this time for this analysis, and from these studies, data for 25 independent groups of about 1800 children were available. Summary statistics for

these groups are reported in Table 1. As part of the sample characteristics,

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Insert Table 1 about here

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both the mean age and age range were obtained and converted into months for each study which provided this information. However, 13 of the 16 studies reported the age range of the children only in terms of grade levels, without any corresponding chronological age equivalents. For these studies, the mean age and age range of the children were estimated by converting each grade level into a 12 month age range. The first grade was estimated as 72 to 84 months, the second grade as 84 to 96 months, and so on. The mean ages for these studies was estimated by using the midpoint of the converted age range. This procedure may have over- or under-estimated either or both of these variables to some extent. However, elimination of these studies would have severely limited the number of groups available for this analysis.

Classification of Piagetian tests

To summarize the various types of Piagetian tests, five main categories for tests of concrete and formal operations were established:

Conservation. This contained subcategories for area, length, quantity, volume and weight. A subcategory for general conservation batteries was included for studies which reported total scores on the Goldschmid-Bentler Concept Assessment Kit, or scores based on a combination

of two or more conservation tests selected by the original authors. A subtotal for all conservation correlations across each group of subjects was calculated, averaging correlations within a study if more than one type of conservation test was reported.

Logical operations. This contained subcategories for class inclusion, classification, relativity, seriation, transitivity, and a general logical operational batteries which contained a combination of two or more logical operations tests. A subtotal for all logical operations correlations across each group of subjects was calculated, averaging correlations within a study if more than one type of logical operation test was reported.

General concrete operational batteries. This contained batteries of tests that combined conservation, logical operations and other concrete operational tests, and yielded a single score across all these tasks.

Spatial concepts. This contained tests of spatial perspectives.

Formal operations. This contained tests of chemistry, correlation and combinational formal operational tests.

Since there were so few studies in these last three categories, the averaged correlations for these categories are not discussed here. Within a particular study, if more than one correlation was available within any of these categories, then these correlations were averaged within that study. Once averaged correlations within studies were obtained, then correlations were averaged across studies, using Fisher's r-to-Z transformation which weights each correlation by the sample size on which each separate correlation is based.

Classification of arithmetic tests

Two main categories of arithmetic tests were used. One included total scores from standardized arithmetic tests such as the MAT, SAT, WRAT, and the Iowa TBS, which were available from 11 studies for 16 groups of children. These scores were reported as grade equivalents by the authors. The second included nonstandardized arithmetic tests designed by the authors of six studies for nine groups of children. These scores were reported as raw scores, and the tests covered areas such as computation, reasoning, number recognition and problem solving.

Results and Discussion

The averaged correlations for conservation and logical operations with standardized and nonstandardized arithmetic tests are illustrated in Figure 1. The averaged correlation between all conservation tasks

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Insert Figure 1 about here

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and standardized arithmetic tests, based on 12 groups, was .42, while the correlation with nonstandardized arithmetic tests, based on eight groups, was .45. The conservation tests which yielded the highest correlations with both types of arithmetic tests were general conservation batteries and conservation of area, both of which yielded averaged correlations of about .47. It is not surprising that a battery of tests such as the Goldschmid-Bentler Kit, or combinations of two or more conservation tests,

yield higher correlations than individual conservation tests, so the superiority of the general conservation battery category can be partly attributed to the large number of tests included in this category. The averaged correlation between conservation of number and both types of arithmetic tests was .43. The lowest conservation and arithmetic correlation occurred on conservation of length, and was .19.

The averaged correlation between all logical operations tests and standardized arithmetic tests, based on six groups, was .59, while the correlation with nonstandardized tests, based on four groups, was .63. The logical operations tests which yielded the highest correlation with both types of arithmetic tests were general logical operational batteries and seriation, both of which yielded correlations of about .64. As mentioned for the general conservation batteries, it is not surprising that the general operations category yielded higher correlations than individual logical operations tasks. The averaged correlation between seriation and arithmetic, based on seven groups, was the highest correlation between any Piagetian task and arithmetic test. The averaged correlations between classification and class inclusion with both types of arithmetic tests were .40 and .38 respectively. In general, correlations between tests of logical operations and arithmetic were higher than those between conservation and arithmetic.

The total averaged correlation across all Piagetian and arithmetic categories, based on 25 groups, was .50, which accounts for approximately

25% of the variance. By way of comparison, the averaged correlation between a variety of standardized reading achievement tests across the same Piagetian categories, based on a separate review of 30 groups (Jordan & Brownlee, 1979), is .43, and this accounts for 18% of the variance. These two sets of correlations are similar, and indicate that Piagetian tests can account for about one quarter of the variance in achievement test performance. It is also interesting to compare the relationship between Piagetian and achievement tests, with the relationship between Piagetian and intelligence tests. The averaged correlations between IQ and MA with the same Piagetian categories, based on another separate review of 37 groups (Jordan & Jordan, 1975), are .33 and .48 respectively. It appears that Piagetian tests are more highly correlated with achievement, than with intelligence tests. However, to complete this comparison, the size of the relationship between achievement and intelligence tests should also be considered. It is frequently reported in the literature that the correlation between intelligence and achievement tests is at least .50 or higher. Unfortunately, it is not possible to estimate at this time how much of the Piagetian-achievement test relationship can be attributed to their mutual relationship with IQ, since none of the studies reviewed for this paper contained partial correlations which would eliminate the contributions of IQ to the Piagetian-achievement relationship. It would be desirable for future studies to obtain information not only on Piagetian and achievement tests, but on intelligence tests as well, so that the independent contribution of Piagetian performance on achievement performance can be measured.

Previous research has indicated that correlations between Piagetian and psychometric tests and chronological age were influenced by the size of the age range of the sample groups (Jordan & Jordan, 1975). To examine whether the size of the age range and mean age of the present sample were related to the size of the correlations between Piagetian and arithmetic tests, Spearman rank-order correlations were obtained between these age-related variables and the Piagetian and arithmetic test correlations. The size of the age range was not related to the size of the Piagetian and arithmetic test correlations. In contrast, an inverse relationship was obtained between the mean age of the total sample and the size of the correlation between Piagetian and arithmetic tests, indicating that groups with younger mean ages tended to have larger correlations than groups with older mean ages. The mean age of the total sample was seven years, seven months, corresponding to second grade, so it appears that Piagetian tests are better predictors of arithmetic achievement for first and second grade children than for older children. Since these grades coincide with the transition from preoperational to concrete operational thought, it is not surprising that this relationship with mean age has occurred. It is likely that as children get older, their performance on Piagetian tests reaches a ceiling level, thereby reducing the amount of variance among the sample and lowering the correlations with achievement tests.

In conclusion, these correlational data suggest that a moderate relationship exists between Piagetian and arithmetic tests. Furthermore,

no systematic differences occurred in the size of the Piagetian-arithmetic correlations between standardized and nonstandardized arithmetic tests. It is possible that a necessary but not sufficient relationship exists between a variety of Piagetian and arithmetic skills. Many conserving children perform higher on arithmetic tests than do their nonconserving peers, although some nonconserving children nevertheless attain comparable levels of arithmetic performance. One implication of these findings might be the use of Piagetian tests as a diagnostic aid for children who are experiencing difficulties in arithmetic, and it is conceivable that remedial experiences in conservation and logical operations might improve their arithmetic achievement.

References

Jordan, V.B., and Brownlee, L.L. Summary and review: Correlational studies of Piagetian tasks and various measures of reading achievement. Paper presented at the 9th annual conference on Piagetian Theory and the Helping Professions, Los Angeles, February 1979.

Jordan, V.B. and Jordan, L.A. Relative strengths of IQ, mental age and chronological age for predicting performance on Piagetian tests. Paper presented at the biennial meeting of the Society for Research in Child Development, Denver, April 1975.

Table 1

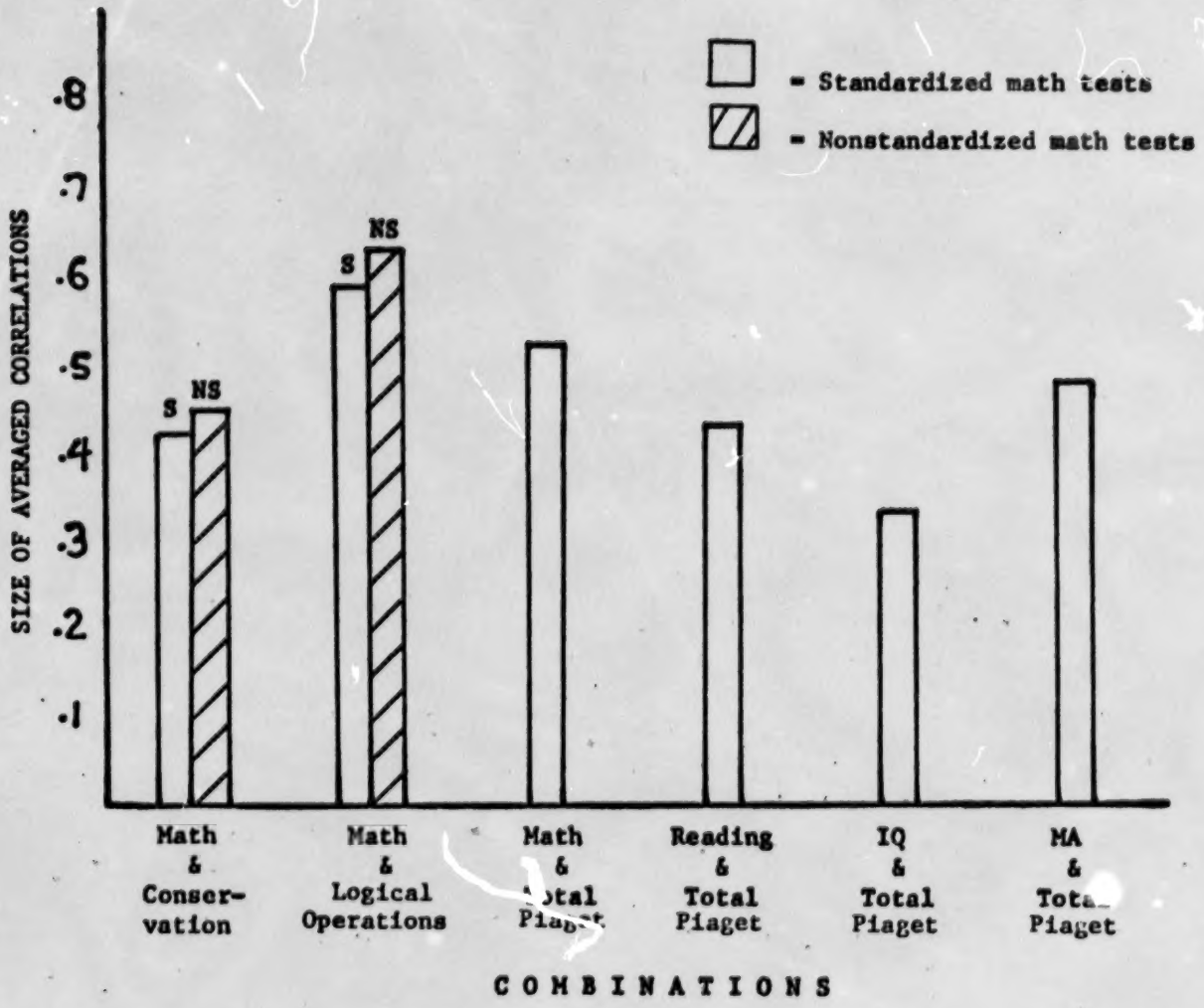
Summary Statistics of Group Characteristics by Type of Arithmetic Test

Group Characteristics	Standardized Tests	Nonstandardized Tests	Total Tests
Average M Age	97	79	91
Range of M Age	66 - 153	65 - 102	65 - 153
M Size of Age Range	16	12	15
Range of Size of Age Range	11 - 50	6 - 25	6 - 50
M IQ	110	104	110
Range of M IQ	106 - 121	-	104 - 121
N of groups	16	9	25

Note. Chronological ages are reported in months.

Figure Caption

Figure 1. Size of averaged correlations between Piagetian tests and mathematics and reading achievement, IQ, and MA.


= Standardized math tests
= Nonstandardized math tests
SIZE OF AVERAGED CORRELATIONS
.8
.7
.6
.5
.4
.3
.2
.1
S
NS
S
NS
Math & Conser-vation
Math & Logical Operations
Math & Total Piaget
Reading & Total Piaget
IQ & Total Piaget
MA & Total Piaget
COMBINATIONS